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COMPARISON OF ANALYSIS TECHNIQUES FOR ELECTROMYOGRAPHIC DATA,(U)
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COMPARISON OF ANALYSIS TECHNIQUES FOR ELECTROMYOGRAPHIC DATA

By

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John C. Johnson, M.S.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Electromyography has been effectively employed to estimate the stress encountered by the forearm flexor muscles in performing a variety of functions in the static environment. Such analysis provides the basis for modification of a man-machine system in order to optimize the performance of individual tasks by reducing muscle stress. Myriad analysis methods have been proposed and employed to convert raw electromyographic data into numerical indices of stress and, more specifically, muscle work. However, the type of analysis technique applied to the data can significantly

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affect the outcome of the experiment. In this study four methods of analysis ~~are employed~~ to simultaneously process electromyographic data. The methods of analysis include the following:

(cont on p 9)

(1) Integrated EMG (three separate time constants);
(2) Root mean square voltage;
(3) Peak height discrimination (three level).
(4) Turns counting (two methods).

Mechanical stress input as applied to the arm of the subjects includes static load and vibration. The study reveals the comparative sensitivity of each of the techniques to changes in EMG resulting from changes in static and dynamic load on the muscle.

The conclusions of the study are:

1. The total integrated electromyographic output and the RMS value of the electromyographic output are both linear functions of applied stress.
2. Within the range of integration time constant evaluated (0.1 - 1.0 msec), the integrated electromyographic activity versus applied stress curve remains highly linear.
3. The peak height discrimination technique and the turns amplitude histogram are both highly sensitive to electromyographic changes induced by vibratory stimuli.
4. Peak height discrimination and turns counting techniques have a very narrow linear dynamic range and are not well suited to studies involving stress variations over a wide range of values.

PREFACE

This research study, involving human subjects, was conducted in accordance with U.S. Army Medical Research and Development Command (USAMRDC) Regulation 70-25, "Use of Human Subjects in Research, Development, Test and Evaluation." The methodology, techniques and risk analysis for this study are described in the precis entitled "Electromyographic analysis of neck and back muscle stresses induced by whole body vibration and asymmetric head loads." Approval for the use of human subjects in conducting the aforementioned research was granted by USAMRDC on 25 May 1976.

ACKNOWLEDGEMENTS

To Mr. Alford A. Higdon and Dr. Heber Jones of the Computer Center I am indebted for their efforts in writing the software which controlled the data acquisition and analysis essential to this project. To Mrs. Anita Drennon and Mrs. Flora Roach I extend my thanks for preparing the manuscript. Lastly, I express my deepest admiration and sympathy to the six men and women who participated as subjects in this experiment and managed to maintain their concentration despite the ever deepening depths of boredom to which they were exposed during the test.

SUMMARY

Electromyography has been effectively employed to estimate the stress encountered by the forearm flexor muscles in performing a variety of functions in the static environment. Such analysis provides the basis for modification of a man-machine system in order to optimize the performance of individual tasks by reducing muscle stress. Myriad analysis methods have been proposed and employed to convert raw electromyographic data into numerical indices of stress and more specifically, muscle work. However, the type of analysis technique applied to the data can significantly affect the outcome of the experiment. In this study four methods of analysis are employed to simultaneously process electromyographic data. The methods of analysis include the following:

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Approved:

Stanley C. Knapp MD

STANLEY C. KNAPP
Colonel, MC
Commanding

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INTRODUCTION

This study was the first in a series of electromyographic experiments to be conducted at the US Army Aeromedical Research Laboratory, Fort Rucker, AL. The purpose of the investigations is to further our understanding of the role which vibration plays in altering the muscular performance and endurance characteristics of human subjects. The results of these studies will be applied directly to an analysis of the effects produced in Army aviators by the vibration encountered in rotary wing aircraft.

The specific goals of these experiments are:

a. to develop a technique of surface electrode application which minimizes the effect of motion artifact,

b. to compare techniques which are commonly used to analyze surface electromyographic data (EMG), and

c. to determine the effect produced by indirect vibration in a well defined group of muscles.

BACKGROUND

Several techniques which process evoked electrical potentials have been developed for estimating the overall activity level of muscle tissue. Electronic integration of full wave rectified electromyographic data (EMG) was used by Lippold[1] to determine a quantitative relationship between muscle tension and the bioelectric output of the muscle. This relationship was found to be linear. Maton[2], however, describes the relationship as quadratic. Rosenfalck[3] suggests that the mean value of full wave rectified EMG activity is a more useful measure of muscle loading, but does not quantify the relationship between muscle tension and mean voltage.

While the effect of weight or tension on the electrical activity in muscle is well defined, the effect of vibration on electrical activity in muscle is not as well documented. Empirical findings of Homma, et al,[4] demonstrate that direct vibratory stimulation of the stretch receptors in muscle tissue elicits an increase in muscle tension and evoked electrical activity in conscious human subjects. In primate studies with anesthetized subjects, this effect was much less pronounced. The conclusion resulting from these studies is that the Tonic Vibration Reflex (TVR) which is responsible for the increase in muscular activity due to vibrational stimuli is complex in nature involving the higher centers of the central nervous system. It was with these studies in mind, that this experiment was designed.

EXPERIMENTAL DESIGN

This experiment was divided into three sections. In the first of these, the electromyographic response of the forearm flexors to a static load was determined. In the second section, the force exerted by the forearm flexors in response to vibratory stimulus was determined. In the third section of the experiment, the electromyographic output of the forearm flexors was determined as a function of vibration under isometric and isotonic conditions.

METHODS AND MATERIALS

The muscle group under study in this experiment was the forearm flexors in the right arm of human volunteers. Six subjects of both sexes (having no known history of neuromuscular disorders) participated in the study. Bipolar electrode placement was determined by palpating the flexor carpi radialis and marking sites approximately 2 cm proximal and distal to the center of the belly of the muscle. The common or ground electrode was located on the medial epicondyle of the same arm. The electrode sites were then abraded and treated with a commercially available electrically conductive skin cleaner. The electrodes were mounted using a research grade electrode paste and adhesive disks. Interelectrode resistances between 400 and 1300 ohms were typical and provided a reliable, low noise preparation.

The data acquisition system for this study is shown in Fig. 1.

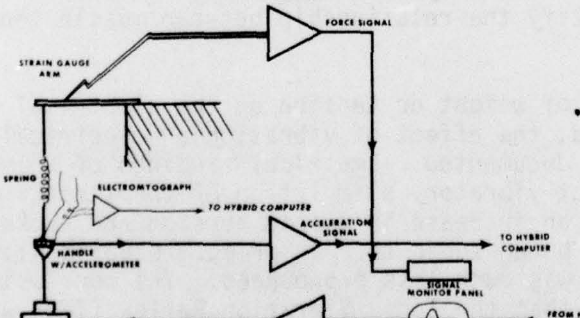

Fig. 1. Data acquisition system.

Following electrode application, the subject was seated in a chair and positioned so that his arm, supine on the arm rest, was in line with the handle of the weight. During data collection, the handle was placed on the metacarpal-phalanx joint of the hand. The weight, an electromagnetic driver used to generate the vibration, was suspended from an electronic scale by an elastic cord as shown in Fig. 2. By raising the handle on the weight by approximately 2.5 cm (1") from its rest position, the subject could increase the static load on his hand from zero to 11 Newtons (2½ lbs). The load signal was available from the electronic scale for recording and for feedback to the subject.

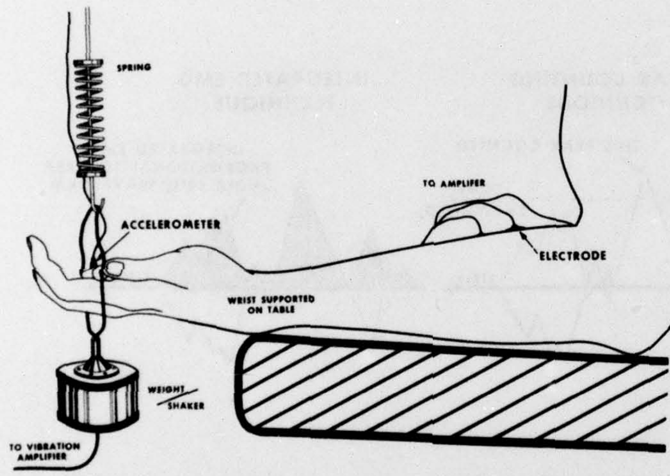

Fig. 2. Subject position during data acquisition.

DATA ANALYSIS

A hybrid computer was used to provide several data reduction functions:

a. Four functions of EMG were calculated: integrated EMG (three different integration time constants), peak height counting (three threshold levels), turns counting (two methods, Fitch[5] and Higdon {unpublished}) and root mean square voltage.

b. The status of the vibration exciter was recorded with other parameters of the experiment such as filter settings, length of test, time of day, identification numbers, and comments made by the investigator.

c. The raw data from the experiment, all of the calculated data described above and documentation data were recorded in real time on digital magnetic tape at a data rate of 2000 samples per second. This permitted

a recorded bandwidth of 1 KHz. Appropriate filtering was used to prevent aliasing effects. The digitally stored raw data was used for power spectral density determinations and correlation function determinations. The calculated data stored on the tape was readily available for statistical analysis after the experiment.

A brief description of the analysis techniques used in this experiment is in order. Full wave integrated EMG analysis consists of full wave rectification of the EMG waveform followed by summation of the area under the curve as shown in Fig. 3. This process was implemented using analog absolute value and integration circuits.

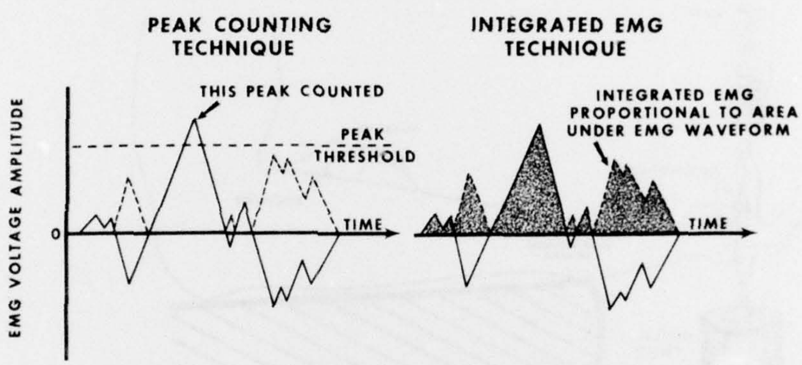

Fig. 3. Comparison of peak counting and integrated EMG techniques.

Peak counting techniques as implemented in this study also required full wave rectification of the waveform. Each time the processed waveform exceeded a threshold, a counter was incremented as shown in Fig. 3. Turns counting techniques used in this study required that the voltage difference between successive changes in direction of the waveform be determined and compared to a reference. When the measured voltage between turns exceeded the reference, a "Turn" was considered to be significant and was counted as shown in Fig. 4. The root mean square value of the EMG waveform was calculated digitally during a two second interval containing 4000 sample points as shown in Fig. 5.

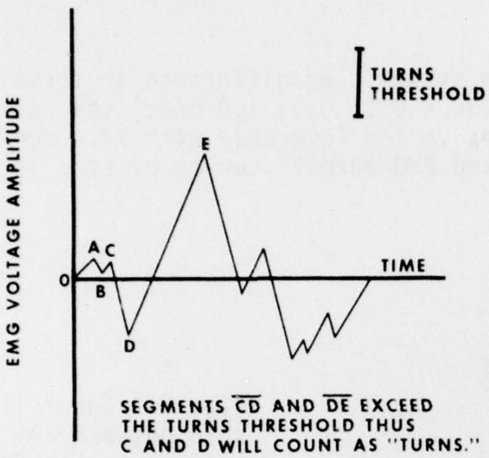

Fig. 4. The turns counting techniques.

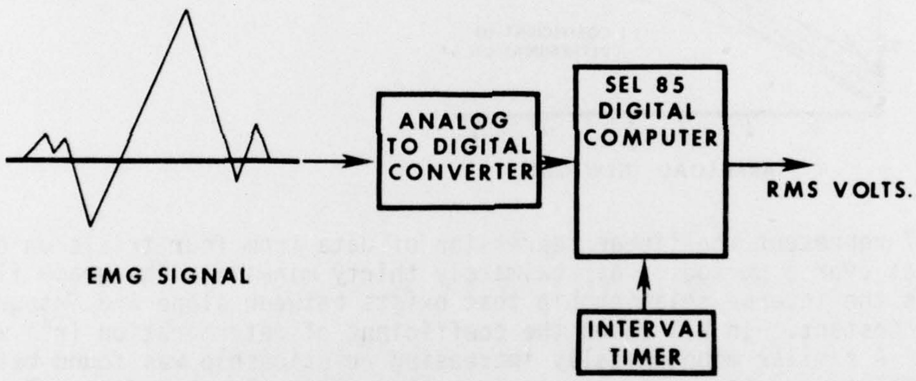

Fig. 5. Root mean square (RMS) voltage computation.

RESULTS AND DISCUSSION

The first section of the experiment, using static loads, produced a linear relationship between applied load and integrated EMG output. An "arm load versus integrated EMG" curve is shown in Fig. 6 for each of the subjects studied. The slope and intercept were determined from the raw data by linear regression. The coefficient of determination (r^2) for each curve is shown and indicates the high degree of linearity attainable with this technique. The slope of each curve was dependent upon the electrode placement, anatomical and physiological peculiarities of the individual, and gain of the instrumentation. The intercept of each curve was dependent upon the resting level of activity in the muscle and upon the

residual noise in the instrumentation system. No difference in curve shape between the three integrators (RC = 0.1, 0.3, 1.0 msec) was noticed although the slope of the curves varied inversely with time constant. The "arm load versus integrated EMG output" curves plotted in

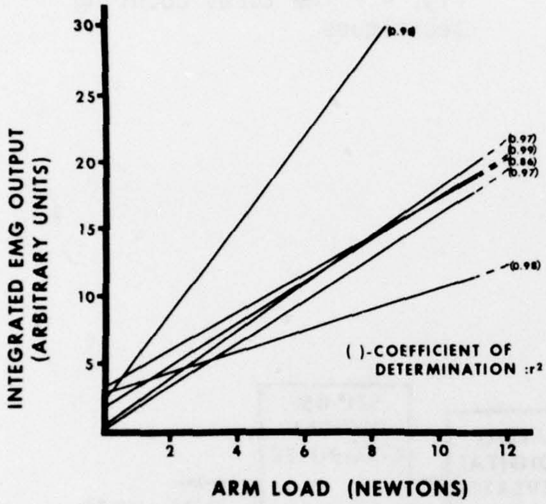

Fig. 6. The relationship between arm load and integrated EMG output for six subjects.

Fig. 7 represent the linear regression of data from four trials on one subject over a period of approximately thirty minutes. The graph illustrates the inverse relationship that exists between slope and integration time constant. In all cases the coefficient of determination (r^2) was 0.92. A similar monotonically increasing relationship was found between static load and the root mean square value of the EMG waveform. For comparison this curve is also shown in Fig. 7. The relationship between load and EMG output for the peak counting technique was linearly increasing for only a short span of the total range of loads applied. Turns

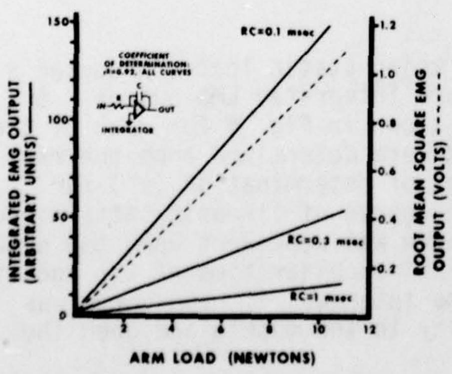

Fig. 7. The effect of integration time constant on the slope of the integrated EMG vs arm load curve.

counting produced a nonlinear curve with considerable scatter in both the static and dynamic case.

When an RMS acceleration of $9.8\ m/s^2$ (1g) was impressed on the weight hanging from the subject's arm, the force exerted by the arm on the load increased as shown in Fig. 8 for a typical subject. This increase in muscle tension was accompanied by an increase in electromyographic activity as

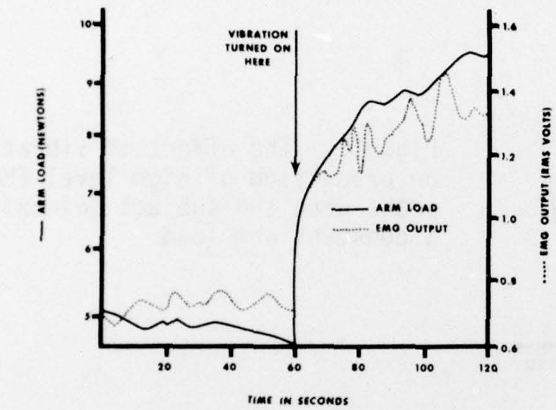

Fig. 8. The effect of vibration on arm load (muscle tension) when the subject received no arm load feedback.

indicated by all of the analysis techniques applied.

When the subject was asked to maintain a constant force on the load handle, electromyographic activity increased as vibration was added to the static load. Some interesting differences appear in the response of the various analysis techniques to EMG data during vibratory stimulation of the muscles. In Fig. 9 the RMS value of the EMG output for a typical subject is plotted as a function of time. In Fig. 10 the integrated value of the same EMG data has been normalized to the scale used in Fig. 9. Note the striking similarity in the shape of these two graphs. This indicates that

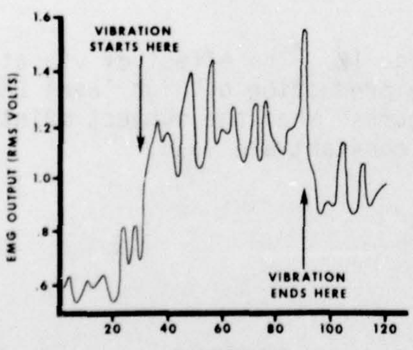

Fig. 9. The effect of vibration on the RMS value of EMG output when the subject maintained a constant arm load.

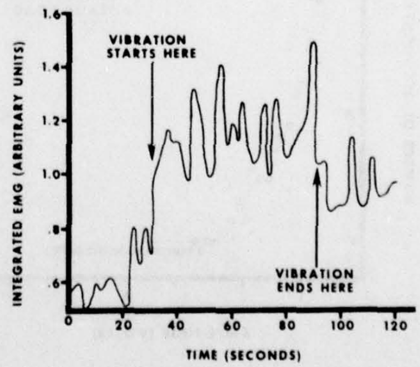

Fig. 10. The effect of vibration on integrated EMG output when the subject maintained a constant arm load.

RMS voltage determination and integrated EMG techniques are essentially equivalent. The number of two volt peaks occurring in this same EMG data during each two second sampling interval is plotted in Fig. 11. This analysis technique indicates a much more pronounced and abrupt increase in electromyographic output at the onset of vibratory stimulation than the RMS and integration techniques.

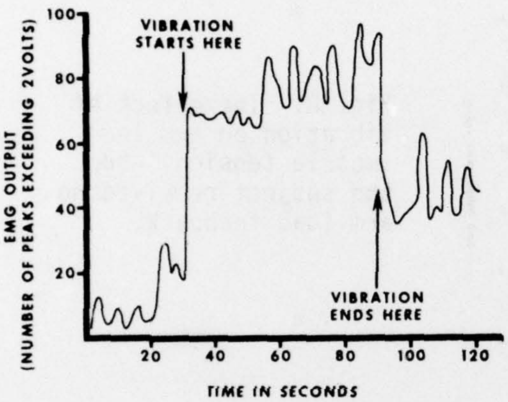

Fig. 11. The effect of vibration on production of high level EMG peaks when the subject maintained a constant arm load.

Single threshold turns counting did not reveal any useful information. However, when a turns histogram[5] was plotted as shown in Fig. 12 for a typical subject, a trend similar to that shown by the peak counting technique is evident. The turns histogram is a graph of the number of turns (vertical axis) having a specific amplitude (horizontal axis) which

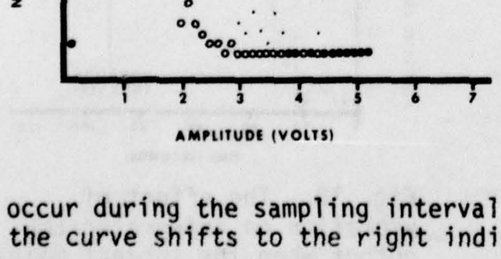

Fig. 12. The effect of vibration on production of high level EMG "turns" when the subject maintained a constant arm load.

occur during the sampling interval. Note that during vibratory stimulation the curve shifts to the right indicating an increase in high amplitude

turns. This finding parallels the increase in two volt peaks noted during vibration in Fig. 11.

CONCLUSIONS

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From this study the following conclusions ~~are~~ were drawn: from this study: (1)

a. Integrated and root mean square voltage parameters provided the smoothest and most linear indicators of muscle activity. (2)

b. Peak counting techniques were more sensitive to change in muscle activity induced by vibration than integrated and RMS techniques; (3)

c. Single threshold turns counting provided no useful information in this experiment; However, the turns amplitude histogram provided information similar to that of multi-threshold peak counting technique; and (4)

d. Changing the integration time constant did not alter the linearity of the relationship between EMG output and arm load.

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1. Electromyography
2. Computer Analysis
3. Vibration
4. Surface Electrodes
5. Tonic Vibration Reflex

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